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Pulsating Forming at Headbox Consistency in Bench Scale Provides Close Imitation of a Single-Wire Machine

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INSTITUTE OF PAPER SCIENCE AND TECHNOLOGY
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To claim realistic laboratory forming, we need to demonstrate that a similar balance between formation and retention can be reached as on machine, with the same furnish. (Granted that the aging of the furnish is likely to be a significant factor, in this study we neglect aging effects. Justifiably one could argue that our furnish is not similar to that used on machine, even if it came from the headbox.) Formation and retention are each affected by the basis weight, so this needs to be held fixed.

Also, the two-sidedness of a product is important. It is well known that smooth drainage in a handsheet mold produces the inverse z-profile of ash, compared with Fourdrinier; instead of wire-side washout, ordinary handsheets display wire-side enrichment. Instead of only looking at average ash loading, we choose to measure and compare layer-wise ash distributions.

Experimental methods

Mill furnish for 89-gpsm offset paper, with 29% PCC, was used throughout the experiments. Dilution for forming at lower consistency used distilled water.

To assess reproducibility of basic mechanical properties of handsheets, tensile index was measured from 15-mm-wide strips with 3-inch span. The relatively short span is due to small handsheet size. Initial testing of basis weight variability was similarly done with cut 15-mm-wide strips to tune the timed profile of vacuum application as well as the stock mixing prior to drainage so as to avoid gross nonuniformity of handsheets.

Ash content was measured by dissolution with hydrochloric acid and titration, both from weighed handsheet pieces and from splits for layer-wise ash determination. Dissolution was aided by heating and sonication.

The splitting to layers was done with adhesive laminate sheets, using a cold laminating machine from 3M.

The basis weight is controlled by stock dosage, i.e., dilution together with amount of diluted stock, as well as the first-pass retention, which is not known a priori. In the exploration stage to create operating curves, the basis weight varied in the range from 66 to 107 gpsm. Stock consistency was between 0.17% and 0.68%.

Belt speed of the MBDT device determines the pulse rate, given a fixed slit configuration of the moving belt. The belt rotates in a closed path around the vacuum suction box and acts like a shutter: vacuum is applied to a point on the wire only when a slit is right underneath it. The belt speed varied in the range from 3 to 16 fps, the maximum speed corresponding to a pulse rate around 75 Hz.

The measured ash content was the target output of an empirical model, the inputs being basis weight, stock consistency, and belt speed. Modeling with a neural network turned out to be more convenient than conventional statistical analysis to generate the operating curves.

The operating curves allow fixing the basis weight and the ash content, while there is still one "degree of freedom" left in the manipulated variables. In practice for each belt speed we can choose a matching dilution level, within some range, and explore the two-sidedness at select points. No further degrees of freedom remain, so given a target value for two-sidedness, the formation will be also determined.

Quantification of formation level was done with the Ambertec formation tester. Target and comparison values for basis weight, ash content, and ash profile (or two-sidedness), as well as formation level, were obtained from mill CD-strip samples.

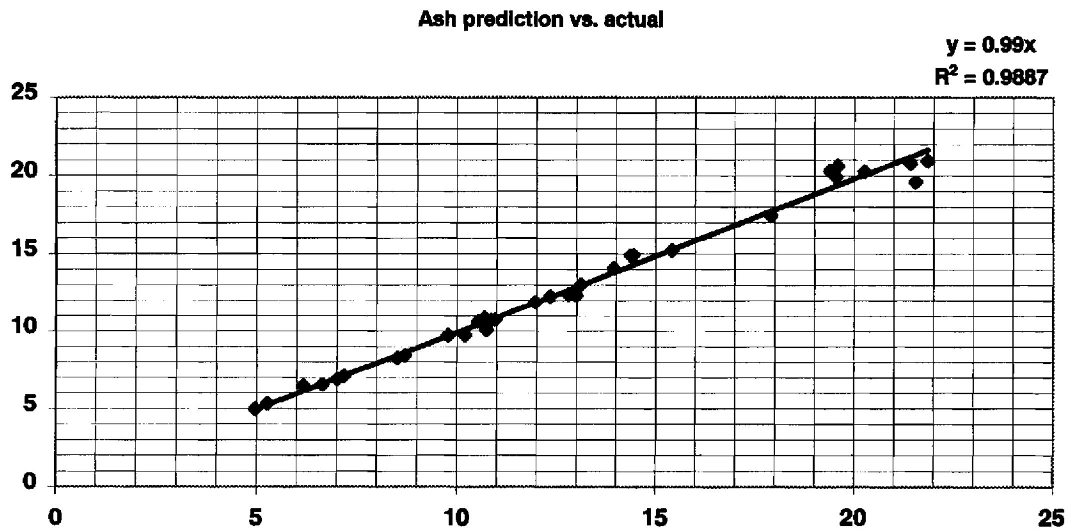

Figure 2. The nonlinear model mapping manipulated variables to the ash content is the basis of our operating curves. Here the model output is compared with ash content measurements, showing that inaccuracies are significant only at the highest ash levels.

Comparison of Figures 3 and 4 illustrates the basis weight effect on retention or ash level in the handsheets. The pulsations cause filler depletion on the wire side, which can be expected to be fairly similar for the two basis weights plotted. Added basis weight can be viewed as adding a top layer to the sheet, and this layer will have high ash content. Therefore, the relative impact on total ash level is strong.

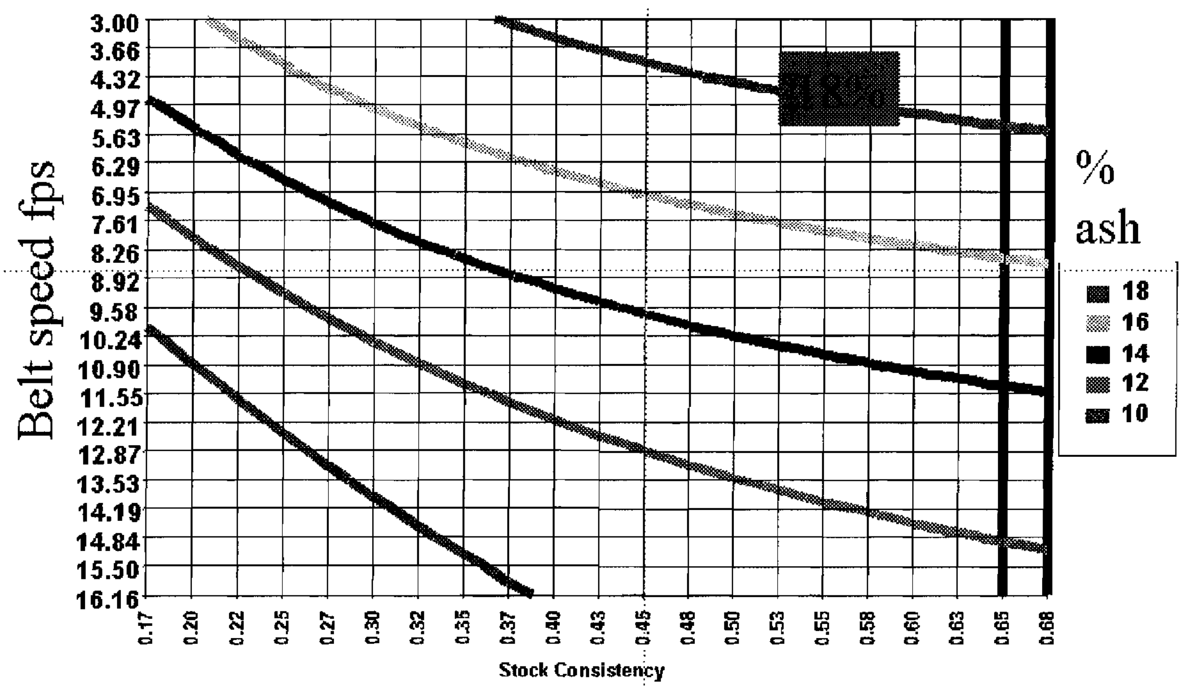

Figure 3. Operating curves showing contours of ash content for 90-gpsm handsheets.

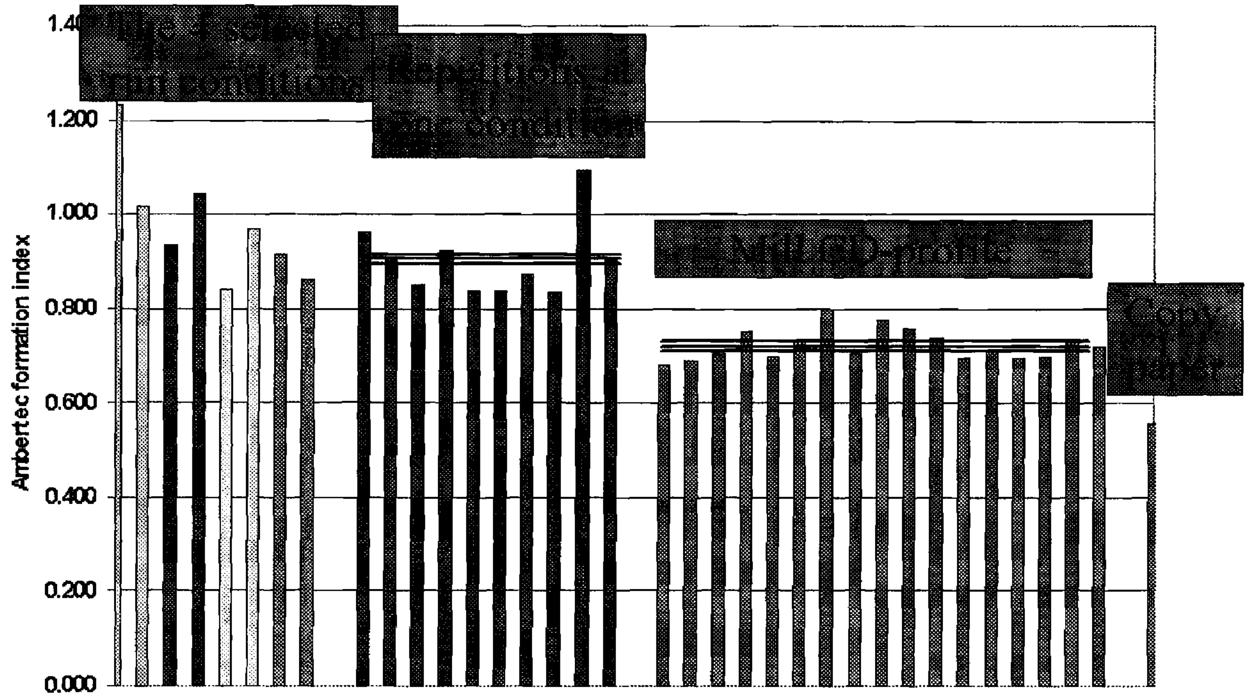

Figure 5. The Ambertec formation indices of MBDT handsheets are compared with a mill CD-strip; lower value is better. The best handsheets from repetitions at 0.5% forming consistency are close to the worst cases of the mill sample. Typical copy paper has significantly better formation, but the furnish would also be different.

Currently we do not know a good way to generate turbulence in the MBDT prior to forming; manual mixing with a plunger is used to avoid swirl patterns generated by rotating mixers. Due to the lack of turbulence and slow forming relative to production machines, it was expected that our handsheet formation should be worse than that of mill paper. We are still contented with this comparison, as it shows that our formation level is not grossly out of range.

The adhesive splitting method for assessing layer-wise PCC content was applied to the handsheet samples formed at four different consistencies. It turned out that at headbox consistency the z-profile of filler was very similar to the machine-made paper. The results are shown in Figure 6.

Note that the splitting is uneven. During the first split, the side with less filler is better bonded. The adhesive backing on the weaker side reinforces the structure to some small depth, causing the minimum strength against splitting at this depth. Therefore tape pulls usually give a thin layer on the side of high filler content. Further layers need to be peeled off from the thick layer to achieve suitable geometric resolution of the filler profile determination.

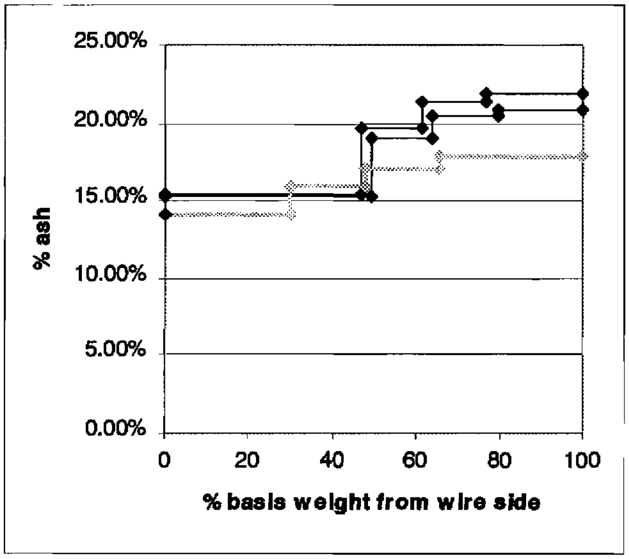

Figure 7. The ash profile can be made less two-sided by lowering the forming consistency and reducing the pulse rate. The result from forming at about 0.3% consistency is shown with the pair of measurements from headbox consistency forming.

Conclusions

1. The Moving Belt Drainage Tester (MBDT) provides consistent and reasonably reproducible handsheet samples.
2. An accurate ash profile measurement for PCC is practiced with adhesive tape splits and a titration procedure.
3. Pulsating forming at headbox consistency was capable of duplicating the total ash level and ash profile of machine-made paper, from headbox furnish.
4. The formation of our handsheets formed at or near headbox consistency is not grossly flawed, but it is slightly worse than that of machine-made paper.
5. Neural network modeling methods were used, and they were handy for producing operating curves to act as graphical guidelines on tuning the operating point of the MBDT device.
6. Pulsating drainage forming in bench scale is closely related to single-wire forming, providing a bench-scale test bed with correct proportions of fiber, filler, water, and additives.
7. We envision that such a test bed will be useful for screening experiments prior to pilot-scale runs, when there are concerns of retention, web structure, and paper properties.

Acknowledgments

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